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**FUEL INJECTION CONTROL SYSTEM  
FOR INTERNAL COMBUSTION ENGINE**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

**[0001]** This nonprovisional application claims priority under 35 U.S.C. § 119(a) on Patent Application No. 2002-265660, filed in Japan on September 11, 2002, the entirety of which is incorporated herein by reference.

**BACKGROUND OF THE INVENTION**

1. Field of the Invention:

**[0002]** The present invention relates to a fuel injection control system for an internal combustion engine. More particularly, the present invention relates to a fuel injection control system in an internal combustion engine in which fuel injection valves have been arranged on the upstream and downstream sides of a throttle valve.

2. Description of Background Art:

**[0003]** When a fuel injection valve is provided upstream from the throttle valve, the volumetric efficiency is improved because heat is taken from intake air when injection fuel vaporizes. Therefore, the engine output can be increased as compared with when the fuel injection valve is provided downstream from the throttle valve.

**[0004]** However, when the fuel injection valve is provided on the upstream side, a response lag occurs in fuel transport as compared with when the fuel injection valve is provided downstream from the throttle valve because a distance between the fuel injection port and a combustion chamber inevitably increases.

**[0005]** Japanese Patent Laid-Open Nos. 4-183949 and 10-196440 discloses a fuel injection system in which fuel injection valves have been provided in the intake pipe at locations upstream and downstream from the throttle valve in order to improve the engine output and cope with the response lag.

**[0006]** Figure 7 is a cross-sectional view showing a major portion of an internal combustion engine according to the background art, in which two fuel injection valves have been arranged with the throttle valve 52 of the intake pipe 51 interposed therebetween. Specifically, a first fuel injection valve 50a has been arranged on the downstream side and a second fuel injection valve 50b has been arranged on the upstream side.

**[0007]** In an internal combustion engine equipped with such fuel injection valves, an accelerated increase in quantity and correction has been experienced, in which an accelerated driving state is detected to increase and correct an injection quantity of fuel. During such accelerated increase in quantity and correction, it is necessary to control an air-fuel ratio in such a manner that fuel does not lag behind an increase in intake air quantity during acceleration. Accordingly, it is requested to quickly increase the quantity of injection fuel. In view of this, in an internal combustion engine equipped with two fuel injection valves, if the fuel for an accelerated increase in quantity and correction is dispersed into both the upstream side and the downstream side, it will become difficult to obtain sufficient acceleration performance due to a response lag which occurs with the injection quantity on the upstream side.

#### **SUMMARY OF THE INVENTION**

**[0008]** It is an object of the present invention to solve the problem of the background art technique described above, and to provide a fuel injection control system, which is excellent in response to the accelerated increase in quantity and

correction in an internal combustion engine in which fuel injection valves are arranged upstream from and downstream from the throttle valve, respectively.

**[0009]** In order to achieve the above-described object, the present invention is directed to a fuel injection system for an internal combustion engine provided with an intake pipe equipped with a throttle valve, an upstream fuel injection valve provided upstream from the throttle valve, and a downstream fuel injection valve provided downstream from the throttle valve. Means are provided for controlling a fuel injection quantity of each of the fuel injection valves on the basis of plural parameters including a throttle opening and the engine speed, and means is provided for detecting an accelerated driving state to increase and correct the quantity of injection fuel. The above-described accelerated increase in quantity and correction increases the injection quantity of the downstream fuel injection valve.

**[0010]** According to the above-described feature, fuel is all injected from the downstream fuel injection valve, the quantity of which has been increased by the accelerated increase in quantity and correction. Accordingly, no response lag is caused in injection of the fuel for the accelerated increase in quantity and correction. Therefore, it is possible to improve the response to the accelerated increase in quantity and correction.

**[0011]** Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0012]** The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

**[0013]** Figure 1 is a general block diagram showing a fuel injection system according to one embodiment of the present invention;

**[0014]** Figure 2 is a functional block diagram for a fuel injection control unit 10;

**[0015]** Figure 3 is a view showing one example of an injection rate table;

**[0016]** Figure 4 is a flowchart showing a control procedure of fuel injection;

**[0017]** Figure 5 is a view showing one example of a PB map;

**[0018]** Figure 6 is a view showing one example of a TH map; and

**[0019]** Figure 7 is a cross-sectional view showing an internal combustion engine according to the background art, in which two fuel injection valves have been arranged.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

**[0020]** A preferred embodiment of the present invention will now be described with reference to the accompanying drawings. Figure 1 is a general block diagram showing a fuel injection system according to one embodiment of the present invention. An intake port 22 and an exhaust port 23 open into a combustion chamber 21 of the engine 20. Each port 22 and 23 is provided with an intake valve 24 and an exhaust valve 25, respectively. An ignition plug 26 is provided extending into the combustion chamber 21.

**[0021]** A throttle valve 28 for adjusting intake air quantity in accordance with its opening  $\theta_{TH}$ , a throttle sensor 5 for detecting the opening  $\theta_{TH}$  and a vacuum sensor

6 for detecting intake manifold vacuum PB are provided on an intake passage 27 leading to the intake port 22. An air cleaner 29 is provided at a terminal of the intake passage 27. Within the air cleaner 29, an air filter 30 is provided. Outside air is taken into the intake passage 27 through the air filter 30.

**[0022]** A downstream injection valve 8b is arranged downstream from the throttle valve 28 in the intake passage 27. An upstream injection valve 8a is arranged on the air cleaner 29 upstream from the throttle valve 28, so as to point toward the intake passage 27. An intake temperature sensor 2 is provided for detecting intake (atmospheric) temperature TA.

**[0023]** An engine speed sensor 4 for detecting engine speed NE on the basis of a rotation angle of a crank is arranged opposite to a crankshaft 33, which is coupled to a piston 31 of the engine 20 through a connecting rod 32. Furthermore, a vehicle speed sensor 7 for detecting vehicle speed V is arranged opposite to a rotor 34, such as a gear, which is coupled to the crankshaft 33 for rotation. A water temperature sensor 3 for detecting cooling water temperature TW representing the engine temperature is provided on a water jacket formed around the engine 20.

**[0024]** An ECU (Engine Control Unit) 1 includes a fuel injection control unit 10 and an ignition timing control unit 11. The fuel injection control unit 10 outputs, on the basis of signals (process values) obtained by each of the above-described sensors, injection signals Qupper and Qlower to each injection valve 8a, 8b on the upstream and downstream sides. Each of the injection signals is a pulse signal having a pulse width responsive to the injection quantity. Each injection valve 8a, 8b is opened by a time corresponding to the pulse width to inject fuel. The ignition timing control unit 11 controls the ignition timing of the ignition plug 26.

**[0025]** Figure 2 is a functional block diagram for the fuel injection control unit 10. It should be noted that the same reference numerals have been used to identify the same or similar elements throughout the several views.

**[0026]** A total injection quantity determination unit 101 determines a total quantity  $Q_{total}$  of fuel to be injected from each fuel injection valve 8a, 8b on the upstream and downstream sides on the basis of the engine speed NE, the throttle opening  $\theta_{TH}$  and the intake pressure PB. An injection rate determination unit 102 refers to an injection rate table on the basis of the engine speed NE and the throttle opening  $\theta_{TH}$  to determine an injection rate  $R_{upper}$  of the upstream injection valve 8a. An injection rate  $R_{lower}$  of the downstream injection valve 8b is determined as  $(1 - R_{upper})$ .

**[0027]** Figure 3 is a view showing an example of the injection rate table. In the present embodiment, an injection rate map includes 15 items ( $C_{ne00}$  to  $C_{ne14}$ ) as a reference for the engine speed NE, and 10 items ( $C_{th0}$  to  $C_{th9}$ ) as a reference for the throttle opening  $\theta_{TH}$ . The injection rate  $R_{upper}$  of the upstream injection valve 8a is registered in advance at each combination of each engine speed NE and throttle opening  $\theta_{TH}$ . The injection rate determination unit 102 determines an injection rate  $R_{upper}$  corresponding to the engine speed NE and the throttle opening  $\theta_{TH}$  that have been detected, by means of four-point interpolation on the injection rate map.

**[0028]** Referring again to Figure 2, a correction factor calculation unit 103 calculates a manifold air pressure correction factor  $K_{pb}$ , an intake temperature correction factor  $K_{ta}$  and a cooling water temperature correction factor  $K_{tw}$  and the like on the basis of process values such as the manifold air pressure PB, the intake temperature TA and the cooling water temperature TW. The correction factor calculation unit 103 further calculates a total correction factor  $K_{total}$  by integrating all of the above correction factors.

**[0029]** An injection quantity correction unit 104 includes an accelerated increase in quantity and correction unit 1041. During acceleration, the injection quantity correction unit 104 increases and corrects the injection quantity of the downstream injection valve 8b for acceleration. In an injection quantity determination

unit 105, an upstream injection quantity determination unit 1051 determines an injection quantity  $Q_{upper}$  of the upstream injection valve 8a on the basis of the injection rate  $R_{upper}$  and the total injection quantity  $Q_{total}$ . A downstream injection quantity determination unit 1052 determines the injection quantity  $Q_{lower}$  of the downstream injection valve 8b on the basis of the upstream injection quantity  $Q_{upper}$  and the total injection quantity  $Q_{total}$ .

**[0030]** Referring to the flowchart of Figure 4, a description will be made of the operation of the fuel injection control unit 10 in detail. This handling is executed by interruption due to a crank pulse in a predetermined stage.

**[0031]** In a step S1, the engine speed  $NE$  is read. In a step S2, the throttle opening  $\theta_{TH}$  is read. In a step S3, an hour rate of change  $\Delta\theta_{TH}$  of the throttle opening  $\theta_{TH}$  is calculated on the basis of a differential between a previous value for the throttle opening  $\theta_{TH}$  obtained by the detecting in the step S2 and this value. In a step S4, the manifold air pressure  $PB$  is read. In a step S5, the hour rate of change  $\Delta\theta_{TH}$  of the throttle opening  $\theta_{TH}$  is compared with a reference rate of change  $\Delta\theta_{THref}$ .

**[0032]** If the rate of change  $\Delta\theta_{TH}$  is below the reference rate of change  $\Delta\theta_{THref}$ , the sequence will proceed to a step S7 because it is determined that the throttle handling is slow and the engine is in a steady state. In the step S7, the  $PB$  map is selected by the total injection quantity determination unit 101.

**[0033]** Figure 5 is a view showing an example of the  $PB$  map. In the present embodiment, 15 items ( $Cne00$  to  $Cne14$ ) are defined as the engine speed  $NE$ , and 10 items ( $Cpb0$  to  $Cpb9$ ) are defined as the manifold air pressure  $PB$ . The total injection quantity  $Q_{total}$  is registered in advance at each combination of each engine speed  $NE$  and manifold air pressure  $PB$ .

**[0034]** In contrast to this, if the rate of change  $\Delta\theta_{TH}$  exceeds the reference rate of change  $\Delta\theta_{THref}$ , the sequence will proceed to a step S6 because the engine is

determined to be in a transient state. In the step S6, the TH map is selected by the total injection quantity determination unit 101.

**[0035]** Figure 6 is a view showing an example of the TH map. In the present embodiment, 15 items (Cne00 to Cne14) are defined as the engine speed NE, and 10 items (Cth0 to Cth9) are defined as the throttle opening  $\theta_{TH}$ . The total injection quantity  $Q_{total}$  is registered in advance at each combination of each engine speed NE and throttle opening  $\theta_{TH}$ .

**[0036]** In a step S8, the PB map 106 is retrieved on the basis of the engine speed NE and the manifold air pressure PB in response to the map selected, or the TH map 107 is retrieved on the basis of the engine speed NE and the throttle opening  $\theta_{TH}$  to calculate the total injection quantity  $Q_{total}$ . The total injection quantity determination unit 101 determines an injection rate  $R_{upper}$  responsive to the engine speed NE and the throttle opening  $\theta_{TH}$  (or manifold air pressure PB) detected by means of four-point interpolation on each of the maps.

**[0037]** In a step S9, in the injection rate determination unit 102, the injection rate table is referred to on the basis of the engine speed NE and the throttle opening  $\theta_{TH}$  to determine the injection rate  $R_{upper}$  of the upstream injection valve 8a.

**[0038]** In a step S10, the injection quantity  $Q_{lower}$  of the downstream injection valve is calculated by adding, to a product of the total injection quantity  $Q_{total}$ , the downstream injection rate  $(1 - R_{upper})$  and a total correction factor  $K_{total}$  obtained by the correction factor calculation unit 103, a predetermined accelerated increase quantity value  $T_{acc}$  further obtained by calculating by the accelerated increase in quantity and correction unit 1041 and an invalid injection time  $T_{iVB}$ . The acceleration corrected quantity  $T_{acc}$  is calculated as a function of, for example, the rate of change of the throttle opening  $\theta_{TH}$  and the manifold air pressure PB. The invalid injection time  $T_{iVB}$  is a time during which perfect injection of fuel is not accomplished.



The invalid injection time  $T_{iVB}$  is determined by the type and structure of the fuel injection valve.

**[0039]** In a step S11, the injection quantity  $Q_{upper}$  of the upstream injection valve is calculated by adding a further invalid injection time  $T_{iVB}$  to a product of the total injection quantity  $Q_{total}$ , the upstream injection rate  $R_{upper}$  and a total correction factor  $K_{total}$  obtained by the correction factor calculation unit 103. In a step S12, a driving signal responsive to the upstream injection quantity  $Q_{upper}$  and the downstream injection quantity  $Q_{lower}$  is supplied to the upstream fuel injection valve 8a and the downstream fuel injection valve 8b. Each fuel injection valve 8a, 8b is opened by a time corresponding to the upper injection quantity  $Q_{upper}$  and the downstream injection quantity  $Q_{lower}$  to inject the fuel.

**[0040]** According to the present invention, all of the fuel is injected from the downstream fuel injection valve, since the quantity of fuel has been increased by the accelerated increase in quantity and correction. Accordingly, no response lag occurs in the injection of the fuel during the accelerated increase in quantity and correction. Accordingly, the response in the accelerated increase in quantity and correction can be improved.

**[0041]** The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.